TENTAMEN TDDD07 Real-time Systems

DATE: 18 August 2009
TIME: 14-18
LOCATION: TER2
RESPONSIBLE TEACHER: Simin Nadjm-Tehrani (Tel: 0702 282412, 013-282411)

Material: English-Swedish-English dictionary
Calculator

No of assignments: 5

Total no. of points: 40

Preliminary grade limits for grades: 3, 4 and 5

3:	20 - 26 p
4:	27 - 33 p
5:	34 - 40 p

INSTRUCTIONS:
Please write your anonymous ID on each sheet of paper that you hand in. Further, pages should only contain one answer per page (answers to sub-questions can be on the same page). You are asked to only write on one side of each paper. Please sort all the sheets that you hand in, in the order of the question number.

Make sure your answers are supported by clear explanations. Figures or charts can be used to provide a clearer explanation but should be accompanied by a textual description. Points will not be given to answers for which the reasoning cannot be followed or that cannot be read due to bad handwriting. You may answer in Swedish or English as you prefer.

Hints: Try to dispose of your time on each question in proportion of the assignment points. In any case where you are in doubt about the question, write down your interpretation and assumptions, and answer the question based on the interpretation. A correct answer that is embedded in errors may give reduction in points, so make sure your answers are to the point.

Results are reported no later than September 3rd.

Good luck!

Simin Nadjm-Tehrani

Q1: Scheduling, QoS

a) Today's agricultural machines are complex systems with many different functions that make it difficult for the driver to operate it. One way of simplifying their work is to make a number of functions automatic to enable less experienced drivers to use the machine. Research prototypes demonstrate how an autopilot can autonomously operate a harvesting machine using different sensors and regulators. Consider a simple autopilot where three processes with the following functions run on the same processor:

- Cruise controller that regulates the number of revolutions for the wheels, where the sampling frequency is 20Hz.
- Directional regulator that decides the angle of wheels in order to follow a haystack for automatic collection of the hay, with a sampling interval of 0,2s.
- CAN controller for managing exchange of data between various subsystems.

Assume that the CAN controller is expected to manage sporadic signals with minimal inter-arrival time of 10ms. Assume further that the processes have the following maximal computation times: cruise controller 20ms, directional regulator 30ms, CAN controller 3ms, and that input jitter from sensors can be ignored.

1. Is the set of processes schedulable with the "rate-monotonic" method? Motivate your answer! (5 points)
2. Assume that the computation taken for scheduling every arriving signal by the CAN controller increases. How does this affect the analysis above? Does the maximal response time for the above three processes become shorter or longer? (3 points)
3. Other than negligible utilisation for the scheduler, what other assumptions are necessary for validity of the analysis under 1 and 2 above? Give two such examples! (2 points)

b) Assume that a new process is to be added to the above process set under part b. The new process should manage a GPS receiver so that the harvesting machine should be able to follow a given route on the field. The process is driven by sporadic events when the driver activates a given trajectory following. Minimal inter-arrival time for the process instances is 300ms and the worst case execution time is 60ms. Does the process continue to be schedulable with rate-monotonic scheduling? Why/why not? Can the process set be scheduled with other scheduling algorithms, such as Earliest-deadline -first? (3 points)

Q2: Dependability

a) Explain the notion of fault tolerance and give one example of it in a real application setting. (2 points)

b) Take a stand on the following propositions (true or false), and motivate your answer:
1) A system that provides its responses in time is reliable.
2) All methods for detecting permanent faults can also be used for detecting transient faults.
3) Dependability of a system is related to the frequency of its failures.

(3 points)

c) Identify the causal chain in following phenomenon in terms of faults, errors and failures.
   1) The autopilot made the Boeing 737-800 aircraft to drop like a stone when a wrong altitude was indicated by an altimeter during landing, leading to a crash at Schiphol airport.

   2) Broadband services were experienced as being slow several hours after the electricity outage was created due to lightning.

   3) University applicants' submitting their applications close to the deadline created access problems before the time of closure for the applications at the central web site.

(3 points)

Q3: Design

a) Are traditional modelling and programming languages adequate for the design of embedded real-time systems? Motivate your answer!

(2 points)

b) If non-determinism is allowed in a modelling language, is the language suitable or unsuitable for designing real-time systems? Why?

(1 point)

Q4: Real-Time Communication

a) Provide 4 differences between the alternative real-time communication techniques that form the basis of TTP and CAN buses respectively .

(4 points)

b) Describe one difference between the underlying model for response time analysis in dynamic scheduling of CAN events and dynamic scheduling of fixed priority processes in a CPU.

(1 point)

Q5: Distributed systems

a) Describe the two methods of bidding and focused addressing in allocation of tasks to distributed nodes in presence of resource constraints.

(4 points)

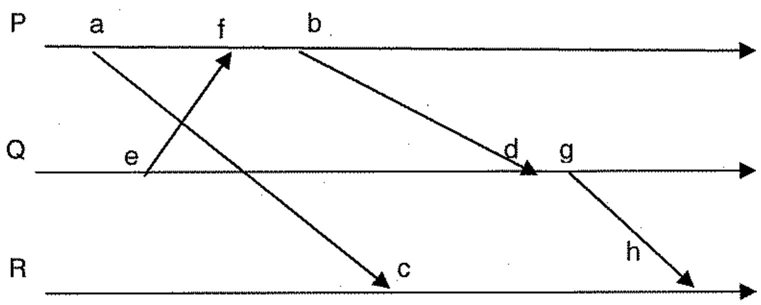
b) What is meant by end-to-end timeliness in a distributed system? Give an example in a realistic application!

(2 points)

c) What is meant by synchronous distributed systems?

(2 points)

d) Identify the vector clocks VC for events c, b, e, d, f and h taking place in processes P, Q, and R below.



(3 points)

Notation for Processes

C = Worst-case execution time
B = Worst-case blocking time
D = Relative deadline
d = Absolute deadline
n = Number of processes
π = Priority
T = Period
R = Worst-case response time
J = Release jitter

Schedulability test for Rate Monotonic:

$$\sum_{i=1}^{n}\left(\frac{C_i}{T_i}\right) \le n(2^{1/n}-1),\ n=1,2,.....$$

With blocking:

$$\forall i,\ 1 \le i \le n: \frac{C_1}{T_1}+\frac{C_2}{T_2}+...+\frac{C_i}{T_i}+\frac{B_i}{T_i} \le i(2^{1/i}-1)$$

Schedulability test Earliest Deadline First:

$$\sum_{i=1}^{n}\left(\frac{C_i}{T_i}\right) \le 1,\ n=1,2,.....$$

RMS Response time analysis

$$w_i = C_i + B_i + \sum_{\forall P_j \in hp(P_i)} \left\lceil \frac{w_i + J_j}{T_j} \right\rceil C_j$$

$$R_i = w_i + J_i$$

$hp(P_i)$ is the set of processes with a higher priority than process P_i.

Timing Analysis of CSMA/CR

B = blocking time
C = transmission time of entire frame
T = period
τ_{bit} = transmission time of one bit
w = response time for the first bit of a frame to be sent
R = total response time
J = Jitter
L = Longest busy interval
$lp(m)$ = set of messages with lower priority than m.
$hp(m)$ = set of messages with higher priority than m.
$hep(m)$ = set of messages with higher or equal priority than m.
n = number of bytes in message (data field)

$$R_m = \max_{q=0..Q_m-1}(R_m(q))$$

$$R_m(q) = J_m + w_m(q) - q \cdot T_m + C_m$$

$$w_m(q) = B_m + q \cdot C_m + \sum_{\forall j \in hp(m)} \left\lceil \frac{w_m(q) + J_j + \tau_{bit}}{T_j} \right\rceil \cdot C_j \quad (\text{with } w_m^{\,0}(q) = 0)$$

$$Q_m = \left\lceil \frac{L_m + J_m}{T_m} \right\rceil$$

$$L_m = B_m + \sum_{j \in hep(m)} \left\lceil \frac{L_m + J_j}{T_j} \right\rceil \cdot C_j \quad (\text{with } L_m^{\,0} = C_m)$$

$$C_m = \left(8n + 47 + \left\lfloor \frac{34 + 8n - 1}{4} \right\rfloor \right) \tau_{bit}$$

$$B_m = \max_{j \in lp(m)}(C_j)$$